

Abstract

The effects of physical size and complexity of metric figures on tactual discrimination performance was investigated with 36 blind children in grades one and two. Metric figures from three levels of complexity (3 X 3, 4 X 4, and 5 X 5) were combined factorially with three physical sizes (1, 2, and 4 inches) in a same-different pair-comparison discrimination task. Increasing levels of physical size and complexity had no effect on discrimination accuracy, but increasing levels of either physical size or complexity significantly increased task time. The results support the conclusion that small tactual figures are discriminated as accurately as large tactual figures, but small tactual figures are discriminated faster than large figures. Overall accuracy of performance was low (62% correct discriminations) and it appeared that unsystematic and inappropriate hand and finger motions were responsible for the low level of performance.

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Effects of Physical Size and Complexity on Tactual Discrimination

Performance of Primary Age Blind Children

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Tactual perception has been described as a process in which information from tactual displays is obtained in a piecemeal and fragmentary serial order (Lashley, 1951; Revesz, 1950). Research in tactual figure perception may be conceived as focusing on those stimulus variables which affect the serial processing of information through the tactual modality.

The physical size of the tactual stimulus has been shown to have an effect on tactual discrimination and recognition performance. Zigler and Northrup (1926) have shown that for common geometric figures (triangle, circle, square, rectangle) there is a threshold (15-20 mm) below which tactual figures cannot be recognized. Obviously, for any given stimulus there is a point at which reductions in physical size will result in reductions in discriminability due to a lack of acuity of the fingertips. However, another question is whether above threshold the absolute or relative size of tactual figures affects discrimination and/or recognition performance. With respect to relative size, Morris and Nolan (1963) have shown that the relative size of different textural patterns affects discrimination accuracy, such that the smaller comparison patterns are than a standard size pattern the less accurate is discrimination performance. Lobb and Friend (1967) using different shaped heptagons, found that the relative size of the figures had an effect on discrimination performance. When the comparison figures were either larger or smaller than the standard figure, recognition performance was less accurate than when both standard and comparison figures were the same size. However, the absolute size of the figures had no effect on recognition accuracy.

Other research in tactual figure perception has focused on the complexity of stimulus figures and its effect on recognition and discrimination performance. Studies by Foulke and Warm, (1967), Owen and Brown, (1970), and Warm, Clarke and Foulke, (1970) have shown that variations in the complexity of tactual metric figures have orderly, quantitative effects on both tactual discrimination and recognition performance. However, little attention has been given to the combined effects of both physical size and complexity on tactual perceptual performance. The absolute size of a tactual figure may be important when used in combination with different levels of complexity.

The effects of physical size on tactual figure discrimination and recognition is important, particularly in the preparation of reading readiness material for blind children. There are a wide variety of commercial and individually prepared reading readiness tasks that are employed to teach young blind children tactual discrimination. However, the size of the tactual figures and the complexity of these figures varies widely within and between the readiness tasks and it is important to determine the effects of these

variables on tactual perception so that maximal efficiency and graded orders of difficulty can be begun to be achieved. The present study was undertaken to investigate the tactual discrimination performance of blind children in grades one and two, varying the physical size and complexity of metric figures in a factorial design.

Method

Subjects

The Ss were 36 braille readers enrolled in schools for the blind. Eighteen Ss from each of grades one and two participated in the study. The means and standard deviations for the ages are as follows: Grade One, $\bar{x}$ age = 8.49, SD = 1.69; Grade Two, $\bar{x}$ age = 9.04, SD = 1.19. The residential schools participating in this research were the Georgia Academy for the Blind, Lavelle School for the Blind, Tennessee School for the Blind, Ohio State School for the Blind, and the West Virginia School for the Blind.

Materials

The stimuli were raised line metric figures. Metric figures are shapes which resemble histograms and are constructed by specific rules as detailed by Alluisi (1960), Baker and Alluisi (1962), and Fitts, Weinstein, Rapaport, Anderson and Leonard (1956). To produce metric figures symmetrical row X column matrices are constructed and then column heights are sampled using one or more rules. A random rule is one in which column heights are sampled randomly. A redundant rule, which is the rule used in this experiment, is one in which column heights are sampled with the constraint that once a specific height has been sampled, it cannot be used again. Examples of figures constructed using this rule for three levels of complexity are shown in Figure 1.

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Insert Figure 1 about here
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Figures from three levels of complexity were constructed using a redundant rule (3 X 3, 4 X 4, and 5 X 5). Complexity is defined by the maximum number of such figures that can be generated from a given row X column matrix. Thus as the number of columns and rows increases the greater the number of figures which can be constructed by sampling column heights. Thus, for example, using a redundant rule in sampling a 3 X 3 matrix, there are only six possible different figures that can be generated (3!) while for a 4 X 4 matrix, twenty-four figures can be generated (4!).

Six figures from each level of complexity were sampled. Each figure was reproduced in three different physical sizes by inscribing each figure within a 1 X 1 inch, 2 X 2 inch, and 4 X 4 inch square. A mold for each figure for each of the physical sizes was constructed and copies of each were reproduced in a vacuum-formed plastic.

Since a pair-comparison technique was employed each figure of a given physical size within a given level of complexity was paired with itself and every other figure and mounted on cardboard and constituted one comparison trial.

Experimental Design

The design consisted of a $2 \times 3 \times 3$ factorial. Effect due to grade level was a between-subjects variable while effects due to complexity and to physical size were within-subjects variables. There were three experimental sessions over three consecutive days. For each session, each S was given 63 trials which consisted of the 21 pair comparisons from each level of complexity of one physical size. Thus Ss received the three levels of complexity in each session, but different physical sizes across days. Within a given experimental session each S received a different order of presentation of the 63 comparison figures and balanced orders of presentation of the three different physical sizes were employed over days.

Procedure

At the beginning of each experimental session the Ss were given five practice trials. These practice trials consisted of same-different responses to each of the following comparisons: circle-triangle, triangle-triangle, triangle-square, hexagon-hexagon, hexagon-triangle. A S was required to obtain four out of five correct choices in order to continue in the experiment. Of the 37 Ss tested, only one failed to meet this criteria. Immediately following the practice trials the Ss were given the experimental trials. During the experimental trials each S was told that he would be presented with two shapes and had to say whether the two shapes were the same or different. Each S was also informed that the E was timing each trial to determine how quickly he could perform the task. Task time was measured from the point at which S placed his hands on the figures to the point at which the S made a response. The Ss were required to compare the two figures simultaneously with the left hand on the left figure and the right hand on the right figure. No feedback was given throughout the experiment.

Results

Two measures of performance were employed: (a) the mean percentage of correct discriminations and (b) the mean task time for correct discriminations.

Since there were two response alternatives per trial and each S had 189 trials over three sessions, the Ss from each grade level had to obtain 56% correct discriminations in order to demonstrate at the .05 level of significance better than chance performance (50%). The levels of performance for both grades one and two were 62%.

The percentage of correct responses for Ss under all conditions was transformed into arcsines (Kirk, 1969) and these data were treated by analysis of variance. No statistically significant differences were obtained for any conditions of the experiment using this dependent measure. See Table 1 for a summary of the analysis of variance.

 Insert Table 1 about here

The mean task time for all Ss under all conditions was transformed into reciprocals (Kirk, 1969) and the data were then treated by analysis of variance. See Table 2 for a summary of the analysis of variance.

 Insert Table 2 about here

The effect due to physical size was significant ($F = 3.94$, $df = 68$, $p < .05$) The means and standard deviations of the task time for each of the three different physical sizes are presented in Table 3. Inspection of Table 3 shows that as the physical size of the stimuli increased, task time increased. These data show that the largest figures took 24% longer to discriminate than the smallest figures.

 Insert Table 3 about here

The effects due to complexity were also significant ($F = 7.51$, $df = 68$, $p < .01$) The means and standard deviations for each of the three levels of complexity are presented in Table 4. These data show that as complexity increased, task time increased. The highest level of complexity took 13% longer to discriminate than the lowest level of complexity.

 Insert Table 4 about here

Discussion

The results of this study support the conclusion that small tactual figures are discriminated as accurately as large tactual figures, but small figures are discriminated faster than large figures. These results are consistent with the conclusions of Lobb and Friend (1967) who showed that the absolute physical size of a tactual figure has no effect on tactual discrimination accuracy. However, it was demonstrated that as the physical size of the stimuli increased, the time necessary to make a tactual discrimination increased. Owen and Brown (1970) have suggested that reaction time, and in this case task time, reflects information gaining, while accuracy of discrimination reflects information processing. Thus it would appear that relative size affects information processing, while absolute size only affects information gaining. In effect, the larger the tactual stimulus the longer it takes to acquire information from the tactual display. In addition, as complexity increased, discrimination time also increased.

The complexity of the stimuli apparently affects the tactual discrimination process in a similar way. However, there are apparently differences in the mechanisms producing the similar increases in task time as a function of either increases in physical size or complexity. As the physical size increases, the perimeter and area of a tactual figure increase and thus there is a greater distance to be traversed requiring more time. On the other hand, as the complexity increases, there is an increase in the number of distinctive features that need to be compared before a decision can be reached. Thus the more distinctive features that are present, the greater the number of comparisons that need to be made, thereby increasing the task time.

The failure to obtain a significant effect of complexity on discrimination accuracy is incongruous with other studies using similar metric figures (Owen and Brown, 1970; Warm, Clarke, and Foulke, 1970). All of these studies have demonstrated orderly quantitative effects of complexity on both figural discrimination and recognition accuracy. The failure to find this effect in the present study could stem from at least two sources. Those studies which have reported significant effects of complexity on discrimination accuracy have all used blind and/or sighted adults, while the present study was conducted with blind children. Thus a developmental factor may have played a role. It may be that young children do not sample or respond to the "complexity" of the stimuli in the same way that adults do. The children may sample less of each figure than the adults and base their decision on less information.

Observations of children exploring these figures suggested that inappropriate finger movements were the principal factors in producing poor performance. Piaget and Inhelder (1967) have mapped the course of the development of hand and finger movements in tactual discrimination. They observe that children who are able to discriminate and recognize tactual figures show finger patterns which are characterized by tracing the outline of the figure and a return to the starting point. Many of the children in this study tended to scan the figures in a seemingly "random" and unsystematic manner and many were observed to trace the outline of the different figures with the right hand traversing the right figure in a clockwise motion, while the left hand traversed the left figure in a counter-clockwise motion. In either case the sequential order of the serial information through the tactual modality would result in a different spatial distribution of the distinctive features and thus lead to erroneous integrations and comparisons of distinctive features. The implications of this research for the education of blind children indicates that reading readiness materials could be made as small as one inch as long as it preserves the integrity of the stimulus. Since absolute physical size had no affect on discrimination accuracy, the teacher may want to select the physical size of a stimulus on the basis of other considerations such as smaller figures to insure appropriate hand and finger motions so necessary for efficient braille reading.

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TABLE 1
 Analysis of Variance for Correct Identifications
 Using Arcsine Transformation of $\bar{x}$ Percentages

SOURCE	<u>df</u>	SS	MS	<u>F</u>
Total	323	59.852		
<u>Between Subjects</u>	35	46.337		
Grades	1	.019	.019	<1
Error	34	46.318	1.360	
<u>Within Subjects</u>	288	13.515		
Size	2	.231	.115	1.52
Size X Grade	2	.300	.150	1.97
Subjs. X Size/Grade	68	5.170	.076	
Complexity	2	.196	.098	2.39
Complexity X Grade	2	.015	.007	<1
Subj. X Complexity/Grade	68	2.756	.041	
Complexity X Size	4	.068	.017	<1
Complexity X Size X Grade	4	.059	.015	<1
Subj. X Size X Complexity/Grade	136	4.718	.035	

TABLE 2
Analysis of Variance for Task Time of Correct
Identification Using Reciprocal Transformation

SOURCE	<u>df</u>	SS	MS	<u>F</u>
Total	323	1.44289		
<u>Between Subjects</u>	35	1.08843		
Grade	1	.06996	.0699	2.34
Error	34	1.01848	.0299	
<u>Within Subjects</u>	288	.35446		
Size	2	.02445	.01226	3.94 *
Size X Grade	2	.00572	.00286	< 1
Subjs X Size/Grade	68	.21116	.00311	
Complexity	2	.00673	.00336	7.51 **
Complexity X Grade	2	.00047	.00024	< 1
Subj X Complexity/Grade	68	.03045	.00045	1.80
Complexity X Size	4	.00376	.00094	1.87
Complexity X Size X Grade	4	.00335	.00084	1.67
Subjs X Size X Complexity/Grade	136	.06836	.00050	

* $p \leq .05$
 ** $p \leq .01$

TABLE 3
Means and Standard Deviations of Task Time (In Seconds) for
Correct Responses as a Function of Physical Size

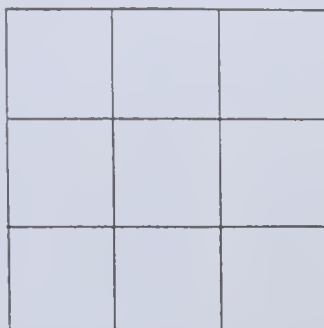
	1"	2"	3"
$\bar{x}$	9.49	10.14	11.75
<u>SD</u>	5.30	4.73	5.87

TABLE 4

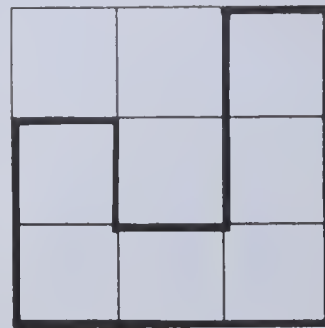
Means and Standard Deviations of Task Times (In Seconds) for
Correct Response as a Function of Complexity

	3 x 3	4 X 4	5 X 5
$\bar{x}$	9.80	10.50	11.08
<u>SD</u>	4.95	5.18	5.96

3 X 3

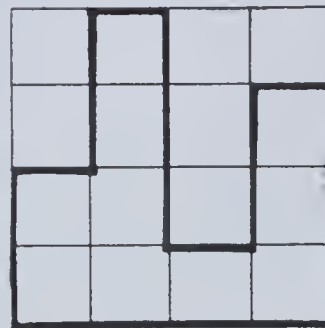
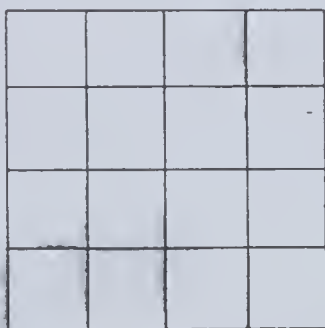


1 2 3

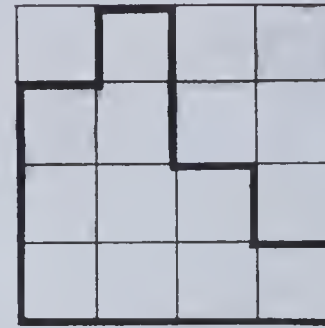


2 1 3

4 X 4

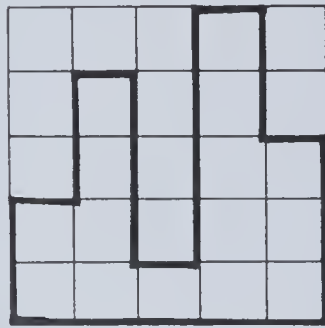
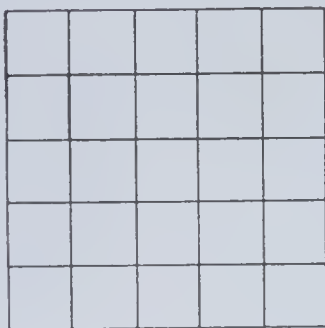


2 4 1 3

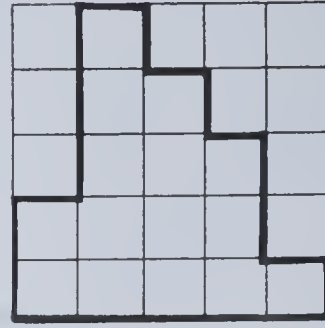


3 4 2 1

5 X 5



2 4 1 5 3



2 5 4 3 1

Fig.1. Examples of redundant metric figures at three levels of complexity.